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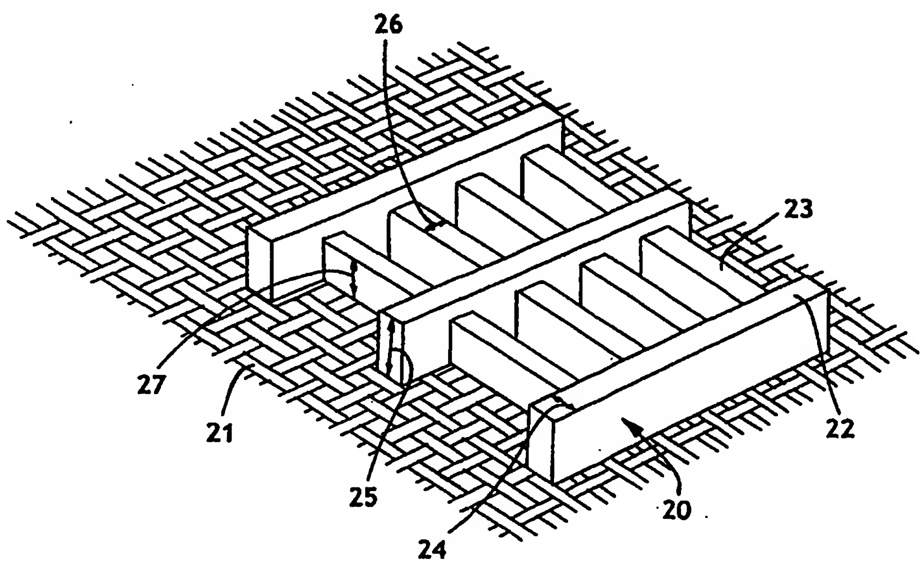

(57) Abstract

A method for making soft tissue includes a "rush" transfer step in which a wet web is transferred from a slower moving fabric to a transfer fabric prior to being throughdried. The transfer fabric has a web-contacting surface which comprises a multi-level nonwoven membrane having a three-dimensional surface. The resulting tissue product exhibits improved physical properties such as bulk, strength, stretch and drape.

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PAPERMAKING PROCESS USING A THREE-DIMENSIONAL RUSH TRANSFER FABRIC

Background of the Invention

In the manufacture of tissue products, such a facial tissue, bath tissue, paper towels, dinner napkins and the like, a number of different processes are available and used commercially. Two well known processes include wet pressing, in which the newly formed wet web is partially dewatered by compressing the web between a papermaking felt and a pressure roll, and throughdrying, in which the web is at least partially dried by passing hot air through the web. The wet pressing process generally includes drying the wet pressed web on a Yankee dryer and creping. The throughdrying process may or may not include creping the dried web.

However, regardless of the manner in which the tissue sheet is made, there is always a need to further improve the properties of the product.

Summary of the Invention

It has now been discovered that several tissue sheet properties can be improved by rush transferring a newly-formed wet web of papermaking fibers to a transfer fabric having a web-contacting surface comprising a multi-level membrane as hereinafter described. The resulting web exhibits a unique combination of properties, particularly in the areas of dry strength, limpness and surface area.

Hence in one aspect, the invention resides in a method of making a tissue sheet comprising: (a) depositing an aqueous suspension of papermaking fibers on a forming fabric to form a layered paper web; (b) transferring the layered web, while at a consistency of about 30 percent or less, to a transfer fabric having a web-contacting surface comprising a multilevel nonwoven membrane, said membrane having a pattern of high ridges and low ridges which surround openings through which water can be removed from the web; (c) transferring the web to a throughdrying fabric; and (d) throughdrying the web.

In carrying out a method of this invention, a relatively wet web (about 30 percent consistency or less) is transferred to a multilevel membrane through which additional water is removed from the web by non-compressive dewatering, such as high differential pressure, vacuum or capillary suction. Because the web is relatively wet, the fibers within the web are still relatively mobile. Consequently, when the web is transferred to the multi-level membrane having a pattern of high and low ridges, the long and short fibers rearrange themselves when contacting the tops and bottoms of the various ridges. The

resulting sheet structure, due to the multiple levels created by the different ridge heights and the reorientation of the fibers, exhibits unique properties in the areas of stretch, strength, limpness and surface area.

The particular multilevel ridge pattern presented by the multi-level membrane can vary greatly. When viewed from the top (plan view), a regular pattern of holes is presented, through which the water in the web is removed. The shape of the holes can round, triangular, square, pentagonal, hexagonal, heptagonal, hexagonal, etc. or irregular. The number of levels presented by the various ridges can be two, three, four or more. The levels can also "blend" into each other in cases where the ridges are not of incremental heights, but rather form a continuum. In all cases, it is essential that the elevated regions of the membrane (above the base) not be monoplanar, which would not be expected to provide all of the desired benefits.

Brief Description of the Drawings

Figure 1 is a schematic process diagram illustrating a throughdrying method for making tissue sheets in accordance with this invention.

Figure 2 is a schematic view of the transfer fabric, illustrating a representative portion of the nonwoven membrane supported by a woven fabric.

Figure 3 is a cross-machine direction (CD)-illuminated surface image photograph (3.8X magnification) of the fabric side (F/S) of a conventional uncreped throughdried sheet, designated as "UCTAD", and a sheet in accordance with this invention, designated as "3A + 1205".

Figure 4 is a surface image photograph of the fabric side of the same tissue sheets illustrated in Figure 3, but illuminated in the machine direction (MD) of the sheets.

Figure 5 is a surface image photograph of the air side of the tissue sheets illustrated in Figure 3, also illuminated with light in the cross-machine direction.

Figure 6 is a surface image photograph similar to that of Figure 5, but illuminated in the machine direction.

Figure 7 is a plot of the geometric mean tensile strength (GMT), expressed in grams, as a function of the rush transfer speed differential, expressed as a percent, when using a transfer fabric in accordance with this invention (3A) versus when using a woven transfer fabric (DD207).

Figure 8 is a plot of the ratio of the caliper to the basis weight for a single sheet, expressed as micron meter/(g/m^2), as a function of the geometric mean tensile strength, expressed in grams, for sheets made in accordance with this invention (3A) as compared to sheets made with a woven transfer fabric (DD207).

Figure 9 is a plot of the total stretch, expressed as percent elongation, as a function of the geometric mean tensile strength, expressed as grams, for sheets made in accordance with this invention as compared to sheets made with a woven transfer fabric.

Figure 10 is a plot similar to that of Figure 9, but showing MD stretch as a function of MD tensile strength for the same samples.

Figure 11 is a plot similar to that of Figure 9, but showing CD stretch as a function of CD tensile strength.

Figure 12 is a plot of the geometric mean slope, expressed as kilograms, as a function of the geometric mean tensile strength, expressed as grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric.

Figure 13 is a plot similar to that of Figure 12, but showing the MD Slope, expressed in kilograms, as a function of the MD tensile strength, expressed in grams.

Figure 14 is a plot similar to that of Figure 12, but showing the CD Slope, expressed in kilograms, as a function of the CD tensile strength, expressed in grams.

Figure 15 is a plot of Dry Burst strength, expressed as grams-millimeters, as a function of the geometric mean tensile strength, expressed as grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric.

Figure 16 is a plot of the Dry Burst strength, expressed as grams-millimeters, as a function of the rush transfer level, expressed as a percent speed difference, comparing sheets made in accordance with this invention (3A) with those made using a woven transfer fabric.

Figure 17 is a table illustrating the difference in z-directional structure for the tissue sheets of this Invention as compared to uncreped throughdried sheets made with a woven transfer fabric. More specifically, the table shows the sheets of this invention have a greater percent coefficient of variation, fewer average percent voids, a shorter mean pore length, and greater correct pore anisotropy.

Figure 18 is a plot of the air permeability, expressed in cubic feet per minute, as a function of the geometric mean tensile strength, expressed in grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric.

Figure 19 is a plot of the air permeability, expressed in cubic feet per minute, as a function of Bulk divided by the basis weight (g/m^2), expressed in micronmeter per gram/m^2, comparing sheets made in accordance with this invention (with two refining levels: 8 minutes and 16 minutes) with those made using a woven transfer fabric (also with refining levels of 8 minutes and 16 minutes).

Definition of Terms and Procedures

As used herein, the following terms shall have the meanings set forth below.

"Air Permeability" is measured by the Frazier Porosity Tester. The rate of air flow through the tissue under a pressure differential between the two surfaces of tissue. The actual air flow can be calculated and expressed in cubic feet per minute.

"Basis weight" is the weight of a tissue sheet per unit area, expressed as grams per square meter.

"Bulk" is the Caliper, as measured below, but expressed in micrometers.

"Caliper" is the thickness of a single tissue sheet measured under a minimal load, expressed in inches. Caliper is measured under laboratory conditions of 23.0 +/- 1.0 degrees Celsius and 50.0 +/- 2.0 percent relative humidity and only after the sheet has equilibrated to the testing conditions for a period of not less than four hours. The micrometer used for carrying out this measurement is an Emveco model 200-A with flat ground, circular pressure foot and anvil and with factory modifications to meet the following specifications: a round pressure foot diameter of 56.42 millimeters (equating to an area of 2500 square millimeters; pressure foot loading of 2.00 kiloPascals; 0 to 7.6 mm test capacity; readout resolution of 0.001 millimeters; repeatability of 0.001 millimeters; linearity of +/- 0.25 percent; dwell time of 3.0 +/- 1.0 seconds; lowering rate of 0.8 millimeters +/- 0.1 per second; and pressure foot and anvil to be parallel within 0.001mm.

"Dry burst strength" is a measure of the tear resistance of a tissue sheet when subjected to a point source of applied force. In general terms, the tissue sample is clamped and suspended horizontally. A foot descends onto the tissue until the tissue tears. The instrument records the peak load required to burst the tissue. More specifically, the dry burst strength is determined by using a Material Test Instrument (MTI) which consists of a foot (model 12), forming cup (model 41, steel ring (model 31), and a 50 gram calibration weight. The test sample is prepared as a single sheet with a size of 5" x 5" (127 x 127 mm) and is maintained at standard conditions (23°C and 50 percent relative humidity) for at least 4 hours. The test is run at the same conditions.

"MD tensile strength" is the machine direction tensile strength of a 3-inches wide sample, expressed in grams. MD tensile strength is measured under laboratory conditions of 23.0 +/- 1.0 degrees Celsius and 50.0 +/- 2.0 percent relative humidity and only after the sheet has equilibrated to the testing conditions for a period of not less than four hours. Testing is done on a constant rate of elongation tensile testing machine. Specimen width is 3 inches. Jaw span (the distance between the jaws, sometimes referred to as gauge length) is 2.0 inches (50.8 mm.) Crosshead speed is 10 inches per minute (254 mm/min.) A load cell / full scale load is chosen so that the majority of peak

load results fall between 20 and 80 percent of the full scale load. In particular the results described here were produced on an Instron 1122 tensile frame connected to a Sintech data acquisition and control system utilizing IMAP software running on a '486 Class' personal computer. This data system records at least 20 load and elongation points per second.

"CD tensile strength" is the cross-machine direction tensile strength of a 3-inches wide sample, expressed in grams, determined as described above for the MD tensile strength.

"Geometric mean tensile strength" (GMT) is a mathematical calculation based on the MD tensile strength and the CD tensile strength to express the overall sheet strength. It is determined by calculating the square root of ((MD tensile strength) x (CD tensile strength)).

"MD stretch" is the percent elongation in the machine direction at the point of failure when determining the MD tensile strength.

"CD stretch" is the percent elongation in the cross-machine direction at the point of failure when determining the CD tensile strength.

"MD Slope" is the two parameter least squares line regression coefficient (sometimes referred to as slope) obtained from the tensile load/elongation curve for all points falling between a load of 70 grams and 157 grams during the ascending part of the curve. The regression coefficient is multiplied by the jaw span and divided by the specimen width to normalize the result, resulting in the final MD Slope value. The MD Slope values may be obtained from the MD tensile curves utilized for the GMT calculation; MD Slope utilizes an identical 3 inch specimen width and two inch jaw span. The units for MD Slope are kilograms per 3 inches (7.62 centimeters), but for convenience, the MD Slope values are hereinafter referred to without units.

"CD Slope" is determined as described above for the MD Slope.

"GM Slope" is a mathematical calculation using the MD slope and the CD slope to express the overall sheet stiffness. It is determined by calculating the square root of ((MD slope) x (CD slope)).

Detailed Description of the Drawings

Referring to the various figures, the invention will be described in greater detail. Figure 1 illustrates a method of making a tissue sheet in accordance with this invention. Shown is a tissue machine for making an uncreped throughdried tissue product. The manufacture of uncreped throughdried tissues is described in U.S. Patent No. 5,672,248 entitled "Method of Making Soft Tissue Products" issued September 30, 1997 to Wendt et

al., which is hereby incorporated by reference. For purposes of this invention, the tissue machine generally includes a layered headbox 1, a forming fabric 2, a transfer fabric 3, a throughdrying (TAD) fabric 4, a throughdrying honey comb roll 5, a forced hot air hood 6, and a reel drum 7. The newly formed web 8 can be homogeneous (not layered) or it can be formed in two or more layers. By way of example, a two layered web can have one layer of eucalyptus fibers (short fibers) and one layer of northern softwood kraft fibers (long fibers). The newly formed web is transferred from the forming fabric to the transfer fabric with assistance from a suitable vacuum box or transfer shoe 9. The transfer is a "rush" transfer in which the forming fabric is traveling at a faster speed than the transfer fabric. The speed differential can be from about 5 to about 30 percent or greater depending upon the amount of stretch to be imparted to the sheet. The consistency of the web at the point of rush transfer can be from about 10 percent to about 30 percent. The resulting web 10 is then transferred from the transfer fabric to the throughdrying fabric with the assistance of vacuum box 11 at a consistency of from about 10 to about 35 percent. The web is then dried on the throughdryer fabric to a consistency of about 95 percent or greater. The dried web 12 is then transferred to the reel 7 and wound up into a parent roll 13.

Figure 2 illustrates a fabric design suitable for use in accordance with this invention as a transfer fabric. Shown is a representative portion of a bi-level nonwoven membrane 20 suitably attached to a representative segment of a woven support fabric 21. While a bi-level membrane is illustrated, multi-level membranes having two or more levels can also be used. The woven support fabric can be any suitable fabric having the desired fiber support and/or air permeability necessary for the position in the process in which the fabric is used. Suitable polyurethane nonwoven membranes are available from Scapa Group PLC, Raleigh, North Carolina. The openings in the membrane can take a variety of shapes. For purposes of illustration, a rectangular design is illustrated in Figure 2.

As shown, the rectangular openings in the membrane are formed by a series of high ridges 22 and low ridges 23. The different heights of the high and low ridges create a bi-level membrane, which is advantageous as will be described below. The geometry of the high and low ridges can vary widely depending upon the desired properties of the resulting tissue sheet. For example, the width 24 of the high ridges can be from about 2.0 mm to about 4.0 mm. The height 25 of the high ridges can be from about 0.1 mm to about 2 mm. The distance between the high ridges (which corresponds to the length of the low ridges) can be from about 1 mm to about 4mm. The width 26 of the low ridges can be from about 1mm to about 4mm. The height 27 of the low ridges is less than the height of the high ridges and can be from about 0.1 to about 2 mm. The distance

between the low ridges can be from about 0.5 mm to about 2mm. The ratio of the distances between the high ridges and the low ridges and their related width and heights will determine the long fiber mass distribution as illustrated below.

The multilevel membrane can be attached to the support fabric with the long ridges oriented in the machine direction, or in the cross-machine direction, or at about 45^0 to the machine direction, or any other angle to the machine direction. Any means for attachment can be used depending upon the durability requirements of the fabric. Sewing the membrane to the support fabric works well.

Figure 3 is a cross-machine direction (CD)-illuminated surface image photograph (3.8X magnification) of the fabric side (F/S) of a conventional uncreped throughdried sheet, designated as "UCTAD", and a sheet in accordance with this invention, designated as "3A + 1205". As used throughout, samples designated as "3A" are samples made using the multi-level nonwoven membrane transfer fabrics in accordance with this invention. The term "fabric side" of the sheet refers to the side of the sheet in contact with the throughdrying fabric as the sheet is dried. Conversely, the "air side" of the sheet is the side of the sheet which is not in contact with the throughdrying fabric while the sheet is being dried. In Figure 3, using CD illumination, there appears to be little difference between the tissue sheet of this invention and that made using a woven transfer fabric.

Figure 4 is a surface image photograph of the fabric side of the same tissue sheets illustrated in Figure 3, but illuminated in the machine direction (MD) of the sheets. In this view, however, a significant difference in the surface structure is apparent between the two samples. More particularly, the surface of the sheet of this invention has greater surface texture and a more three dimensional appearance than the sheet made with a woven rush transfer fabric.

Figure 5 is a surface image photograph of the air side of the tissue sheets illustrated in Figure 3, also illuminated with light in the cross-machine direction. There is no significant difference in surface pattern between these two tissues. They both exhibited the pattern of throughdrying fabric.

Figure 6 is a surface image photograph similar to that of Figure 5, but illuminated in the machine direction. Again, there is a significant difference between the two samples. The tissue sheet of this invention has a non-patterned crepe-like appearance. Conversely, the conventional UCTAD tissue has a more defined throughdrying fabric pattern.

Figure 7 is a plot of the geometric mean tensile strength (GMT), expressed in grams, as a function of the rush transfer speed differential, expressed as a percent, when using a transfer fabric in accordance with this invention (3A) versus when using a woven

transfer fabric (DD207). This plot indicates that using the method of this invention, greater strength is retained for a given level of rush transfer.

Figure 8 is a plot of the ratio of the caliper to the basis weight (bulk) for a single sheet, expressed as cubic centimeters per gram, as a function of the geometric mean tensile strength, expressed in grams, for sheets made in accordance with this invention (3A) as compared to sheets made with a woven transfer fabric (DD207). As shown, the sheet of this invention exhibits significantly greater bulk for a given level of strength, which is very desirable.

Figure 9 is a plot of the total stretch, expressed as percent elongation, as a function of the geometric mean tensile strength, expressed as grams, for sheets made in accordance with this invention as compared to sheets made with a woven transfer fabric. As shown, the sheets of this invention exhibit greater stretch for a given level of strength, which is desirable.

Figure 10 is a plot similar to that of Figure 9, but showing MD stretch as a function of MD tensile strength for the same samples. The result is similar to that of Figure 9.

Figure 11 is a plot similar to that of Figure 9, but showing CD stretch as a function of CD tensile strength. The result is similar to that of Figure 9. The results of Figure 10 and 11 demonstrate that the tissue made with this invention will increase the stretches of tissue in both MD and CD directions. This is a very desirable tissue characteristics as it will increase the dry burst strength as described later.

Figure 12 is a plot of the geometric mean slope, expressed as kilograms, as a function of the geometric mean tensile strength, expressed as grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric. As shown, the sheets of this invention have a lower geometric mean slope at a given level of strength over most of the strength range plotted. A lower slope value correlates with lower stiffness. Insofar as this strength range represents the practical range for most tissue products, this result is very desirable.

Figure 13 is a plot similar to that of Figure 12, but showing the MD Slope, expressed in kilograms, as a function of the MD tensile strength, expressed in grams. The results are similar to those of Figure 12.

Figure 14 is a plot similar to that of Figure 12, but showing the CD Slope, expressed in kilograms, as a function of the CD tensile strength, expressed in grams. The results are similar to those of Figure 12. Again, the tissue made in accordance with this invention method exhibits lower slopes in both the MD and CD directions, as compared to that of conventional UCTAD tissue. Lower slopes for both directions (MD and CD) will

improve the overall drapery feel of the sheet, which correlates with the perception of softness and is very important to the consumer.

Figure 15 is a plot of Dry Burst strength, expressed as grams-millimeters, as a function of the geometric mean tensile strength, expressed as grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric. As shown, the sheets of this invention exhibit higher burst strength at a given strength level than those made using a woven transfer fabric. A tissue with higher dry burst at a given strength will provide a higher resistance for poke through. Higher poke through resistance is a desirable tissue property for the consumer during usage.

Figure 16 is a plot of the Dry Burst strength, expressed as grams-millimeters, as a function of the rush transfer level, expressed as a percent speed difference, comparing sheets made in accordance with this invention (3A) with those made using a woven transfer fabric. The sheets made in accordance with this invention exhibit higher dry burst strength for a given level of rush transfer.

Figure 17 is a table illustrating the difference in z-directional structure for the tissue sheets of this Invention as compared to uncreped throughdried sheets made with a woven transfer fabric. More specifically, the table shows the sheets of this invention have a greater percent coefficient of variation, fewer average percent voids, a shorter mean pore length, and greater corrected pore anisotropy. The shorter mean pore length indicates a more uniform fiber network arrangement in the Z-direction as compared to that of conventional UCTAD tissue. A tissue having a more uniformed pore size distribution will improve the light deflection resulting in higher tissue opacity. It could also enhance the liquid absorbent rate. Pore anisotropy is an indication of the orientation of pore in the tissue structure. A pore anisotropy number of "1" means the pore is oriented vertically or along the Z-direction of the sheet. A pore anisotropy number of "0" means the pore is oriented along the XY plain. The method of this invention will arrange the fibers in such a way that the pore orientation tilts toward the Z direction. More specifically, this invention is able to create a tissue with a pore orientation (namely, pore anisotropy) of 0.450 or greater (25° or greater). A tissue with higher pore anisotropy will increase the liquid absorbent rate and reduce the light transmission through the sheet. Both are desirable attributes for the consumer.

Figure 18 is a plot of the air permeability, expressed in cubic feet per minute, as a function of the geometric mean tensile strength, expressed in grams, comparing sheets made in accordance with this invention with those made using a woven transfer fabric. As shown, the sheets of this invention have a greater air permeability at a given level of strength. For a given conventional tissue making process, the air permeability of a tissue

is directly related its strength. A higher strength sheet will have a denser fiber network which results in a lower capability for allowing air to pass through. This invention is able to create a tissue having a higher air permeability at a given strength in an uncreped throughdried tissue making process. The air permeability measurement is also frequently used as an indication of the fiber-bonding structure. The comparison of the samples of this invention versus the samples of conventional throughdried tissue suggests that there is a structural difference between the two tissues.

Figure 19 is a plot of the air permeability, expressed in cubic feet per minute, as a function of Bulk/BW, expressed in units micrometers/(g/m^2), comparing sheets made in accordance with this invention (with two refining levels: 8 minutes and 16 minutes) with those made using a woven transfer fabric (also with refining levels of 8 minutes and 16 minutes). The bulk/basis weight ratio can be viewed as the volume of material in z-direction (bulk) for a given amount of fibers (basis weight). Conversely, the basis weight/bulk ratio represents the densification of the tissue. The data shown in Figure 19 suggests that for a given density of tissue, the tissue of this invention has lower air permeability than that of conventional UCTAD tissue. Combining the results from Figures 18 and 19, the tissues of this invention exhibit a smaller pore size distribution as compared with that of conventional UCTAD tissue. This is also verified by the data of Figure 17. A tissue with a smaller pore size distribution is desirable because it may improve sheet strength, sheet opacity, liquid transfer rate, and liquid wicking rate.

Examples

Examples 1-3 (Controls). Using three different levels of rush transfer, three throughdried tissue sheets were made generally as described in connection with Figure 1, but **without** using a multi-level nonwoven membrane/fabric in accordance with this invention. More specifically, a two-layered tissue web was formed on a forming wire using a two-layered headbox. The layer basis weight split was 50/50. The layer in contact with the forming fabric (and ultimately also contacting the throughdrying fabric) was 100 percent long fibers (northern softwood kraft). The opposite layer (the air side layer) was 100 percent short fibers (eucalyptus). The newly-formed web was transferred to a conventional woven transfer fabric (DD207) at a consistency of about 18-22 percent with rush transfer speed differences of 10, 18 and 26 percent, respectively. After the rush transfer, while still at a consistency of about 18-22 percent, the web was transferred to an Appleton Mills 1205 woven throughdrying fabric with the aid of a vacuum box. The vacuum level was about 10-20 inches of water. The sheet was throughdried to a consistency of 98 percent and wound up into a parent roll. Samples from the parent roll

were collected and conditioned under standard TAPPI conditions for 24 hours. The conditioned samples were then submitted for physical property testing. The results are set forth in the table below, where "RT" is the rush transfer level, "BW" is the basis weight, "MDT" is the MD tensile strength, "MDST" is the MD stretch, "CDT" is the CD tensile strength, and "CDST" is the CD stretch. The other terms are defined above.

RT	BW (g/m2)	Caliper (um)	Dry Burst (gxmm)	MDT (g)	MDST (%)	MD Slope (kg)	CDT (g)	CDST (%)	CD Slope (kg)	GMT (g)	Air Perm (cfm)	GM Slope) (kg)
10%	29.4	305	660	2153	7.1	38.61	1384	4.04	30.16	1727	113.6	34.12
18%	28.84	314	591	1102	8.0	28.02	1167	4.85	28.14	1134	137.2	28.08
26%	28.04	327	540	873	11.2	25.94	965	4.71	25.03	918	154.0	25.48

<u>Examples 4-6</u> (Invention). Three tissue sheets were made as described in Examples 1-3, using the same three levels of rush transfer, except the woven transfer fabric was replaced with a transfer fabric having a bi-level nonwoven membrane sewn on top of an Aston 44GST fabric as illustrated in Figure 2. The process parameters and their ranges were equivalent to those of Example 1. The parameters of the nonwoven membrane were as follows:

High ridge width (16): 2.22mm

Distance between the high ridges: 0.7mm

High ridge height: 2mm

Low ridge width: 3.33mm

Distance between low ridges: 1mm

Low ridge height: 0.5mm

The physical properties are set forth in the table below.

RT	BW (g/m2)	Caliper (um)	Dry Burst (g.mm)	MDT (g)	MDST (%)	MD Slope (kg)	CDT (g)	CDST (%)	CD Slope (kg)	GMT (g)	Air Perm (cfm)	GM Slope (kg)
10%	28.47	323	806	2281	7.8	35.56	1491	5.38	31.26	1844	123.0	33.34
18%	28.01	358	763	927	17.6	10.05	1206	5.94	24.41	1310	147.6	20.59
26%	28.04	376	698	927	17.6	10.05	1152	6.39	23.13	1033	154.4	15.25

The results of Examples 1-6 above are further illustrated in Figures 3-21 described above.

It will be appreciated that the foregoing examples, given for purposes of illustration, shall not be construed as limiting the scope of this invention, which is defined by the following claims and all equivalents thereto.

I claim:

1. A method of making a tissue sheet comprising: (a) depositing an aqueous suspension of papermaking fibers on a forming fabric to form a layered paper web; (b) transferring the layered web, while at a consistency of about 30 percent or less, to a transfer fabric having a web-contacting surface comprising a multilevel nonwoven membrane, said membrane having a pattern of high ridges and low ridges which surround openings through which water can be removed from the web; (c) transferring the web to a throughdrying fabric; and (d) throughdrying the web.

2. The method of claim 1 wherein the layered web is rush transferred from the forming fabric to the transfer fabric, such that the forming fabric is travelling at a speed from about 5 to about 30 percent faster than the transfer fabric.

3. The method of claim 1 wherein the consistency of the web during transfer to the transfer fabric is from about 10 to about 30 percent.

4. The method of claim 1 wherein the nonwoven membrane is a bi-level membrane.

5. The method of claim 1 wherein the high ridges have a height of from about 0.1 to about 2 millimeters and a width of about 2 to about 4 millimeters.

6. The method of claim 1 wherein the low ridges have a width of from about 1 to about 4 millimeters and a height lower than the height of the high ridges and which is from about 0.1 to about 2 millimeters.

7. The method of claim 1 wherein the distance between the high ridges is from about 1 to about 4 millimeters.

8. The method of claim 1 wherein the distance between the low ridges is from about 0.5 to about 2 millimeters.

9. The method of claim 1 wherein the multi-level membrane is supported by a woven fabric.

10. A tissue sheet made by the method of claim 1.

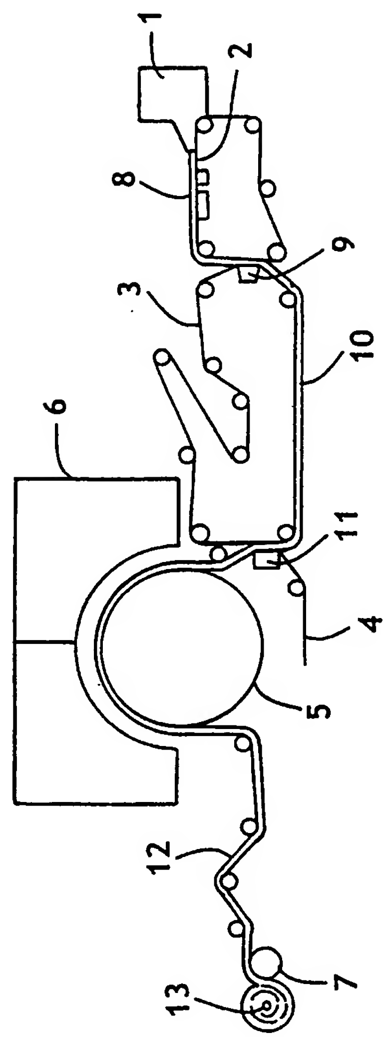


FIG. 1

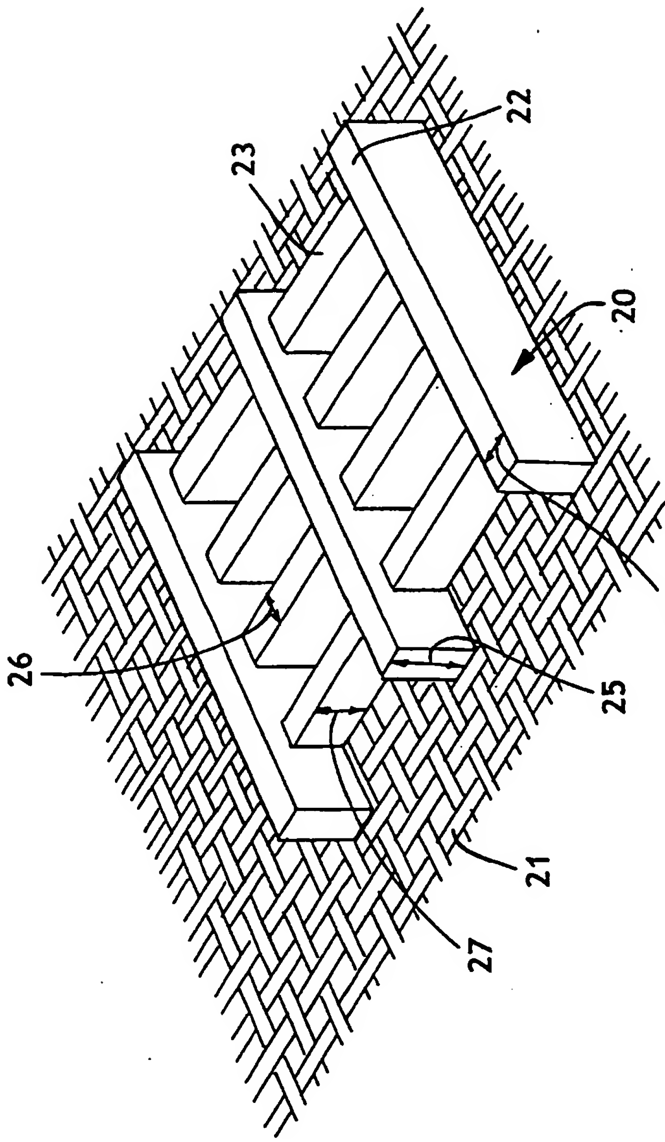
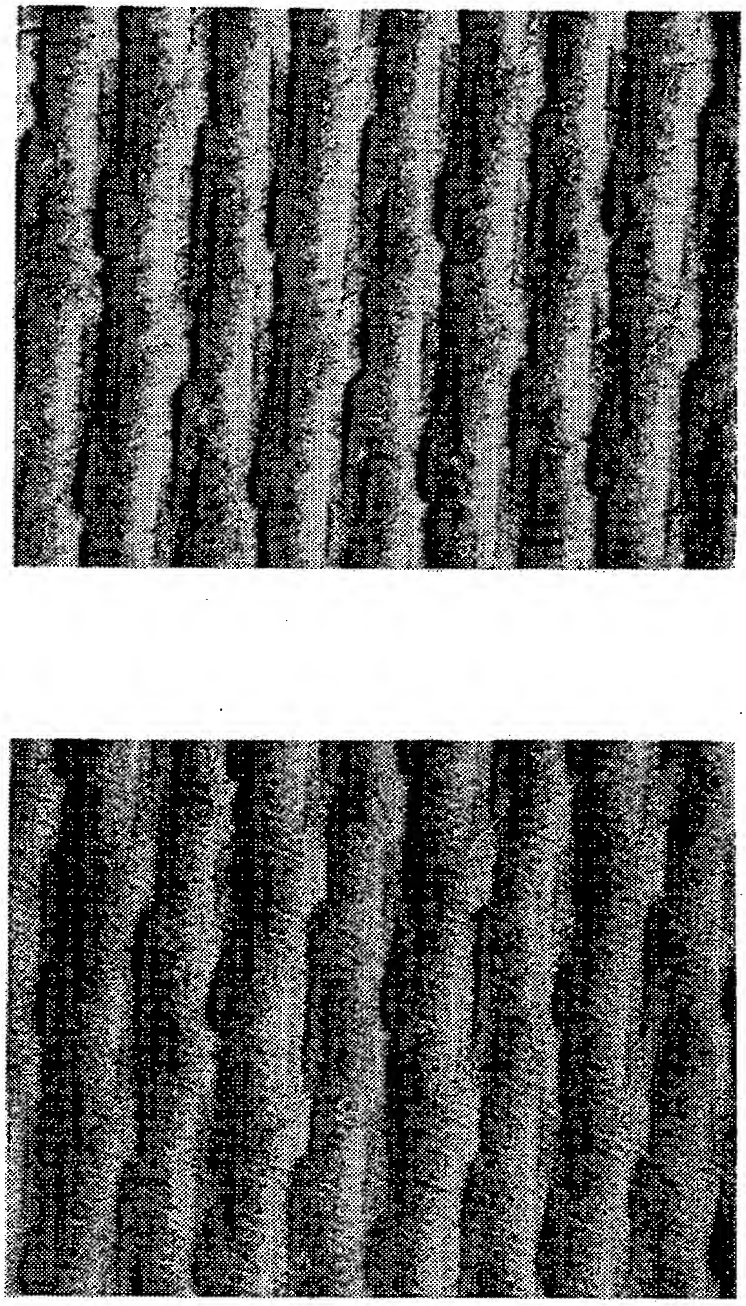


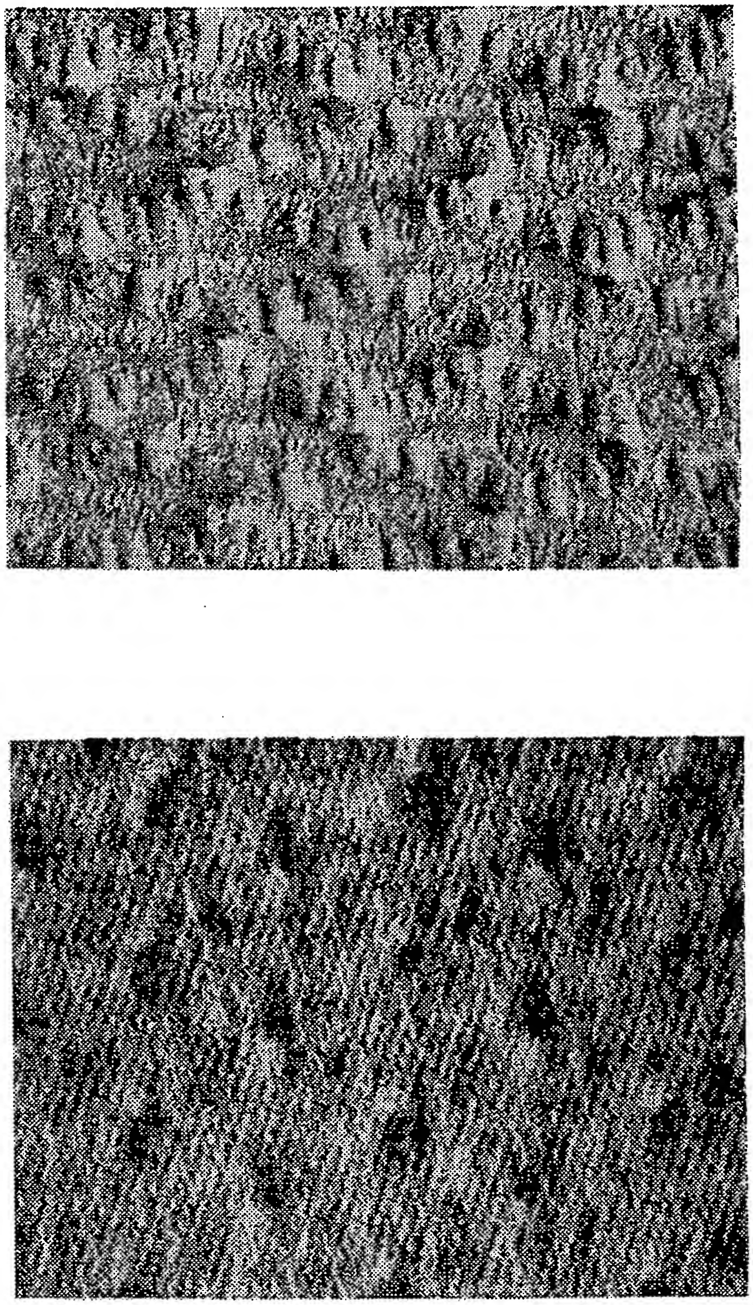
FIG. 2



3A+1205 - (F/S)
CD Light

UCTAD - (F/S)
CD Light

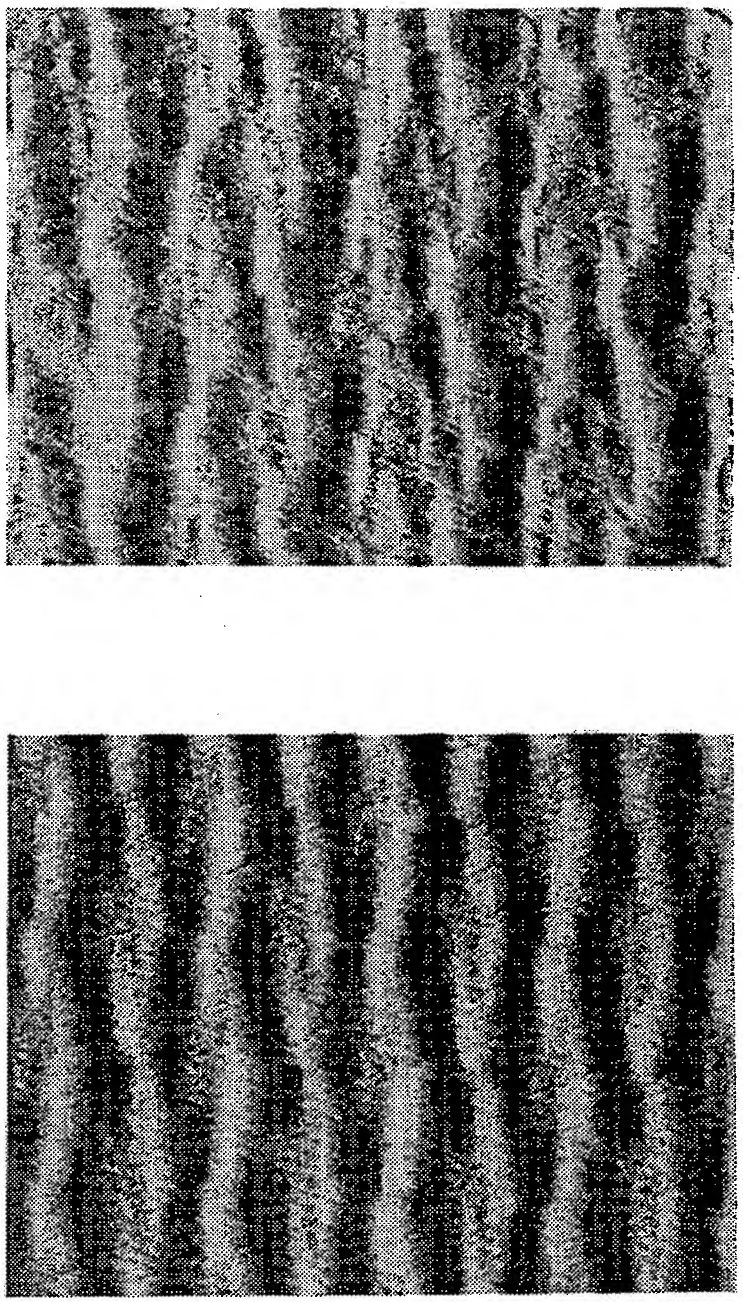
FIG. 3



3A+1205 - (F/S)
MD Light

UCTAD - (F/S)
MD Light

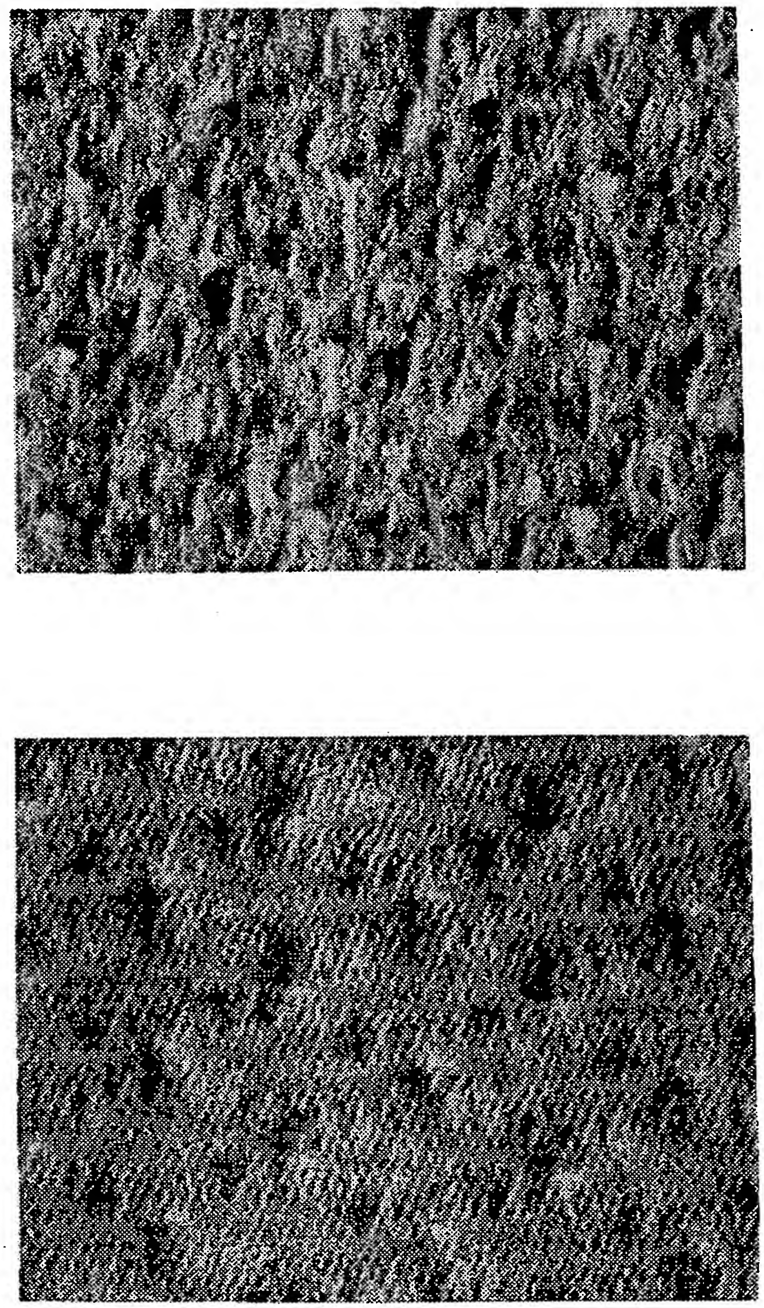
FIG. 4



UCTAD - (A/S)
CD Light

3A+1205 - (A/S)
CD Light

FIG. 5



3A+1205 - (A/S)
MD Light

UCTAD - (A/S)
MD Light

FIG. 6

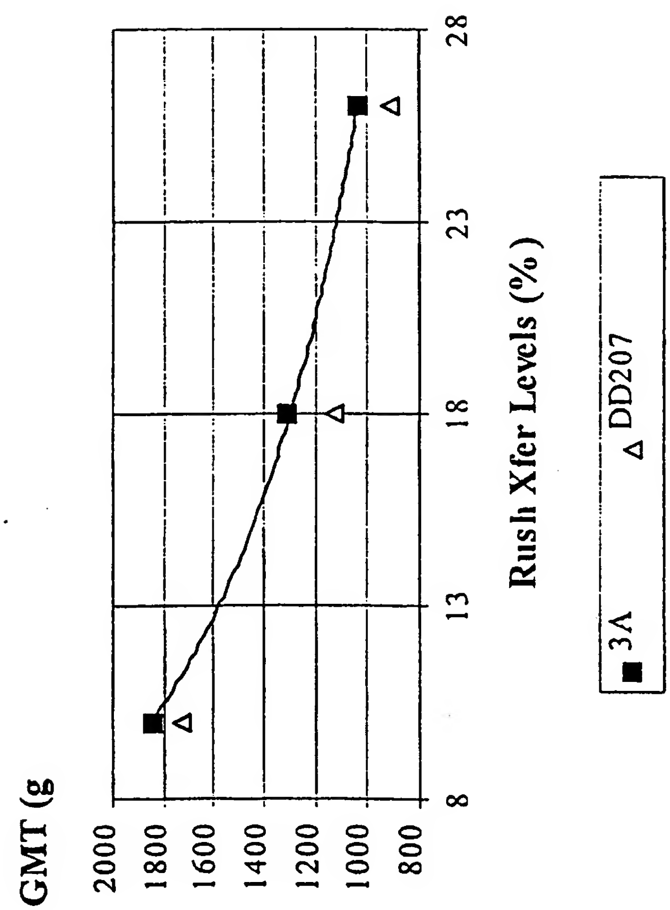

GMT (g
2000
1800
1600
1400
1200
1000
800
8
13
18
23
28
Rush Xfer Levels (%)
3A
DD207

FIG. 7

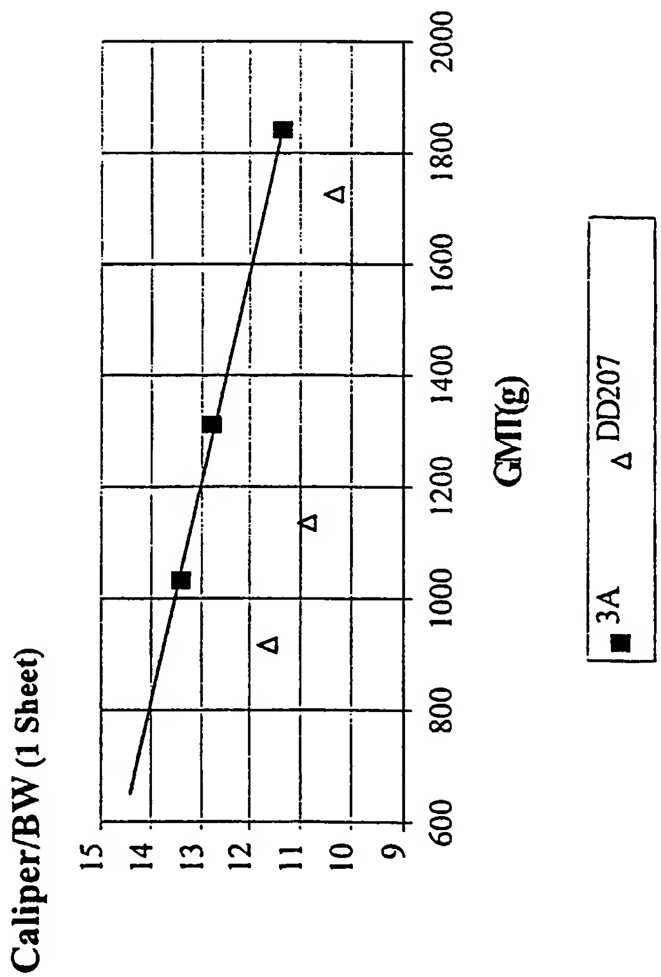

Caliper/BW (1 Sheet)
15
14
13
12
11
10
9
600
800
1000
1200
1400
1600
1800
2000
GMT(g)
3A
DD207

FIG. 8

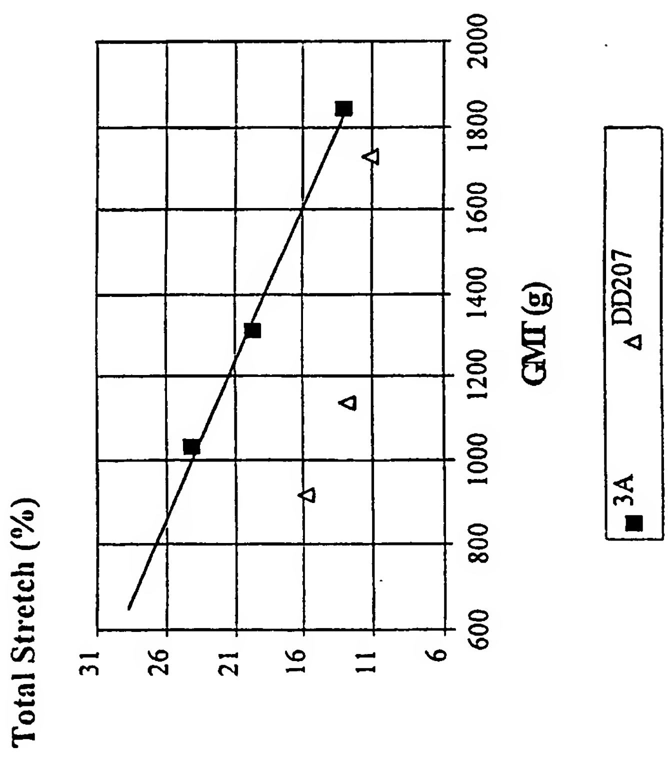

Total Stretch (%)
31
26
21
16
11
6
600
800
1000
1200
1400
1600
1800
2000
GMT (g)
3A
DD207

FIG. 9

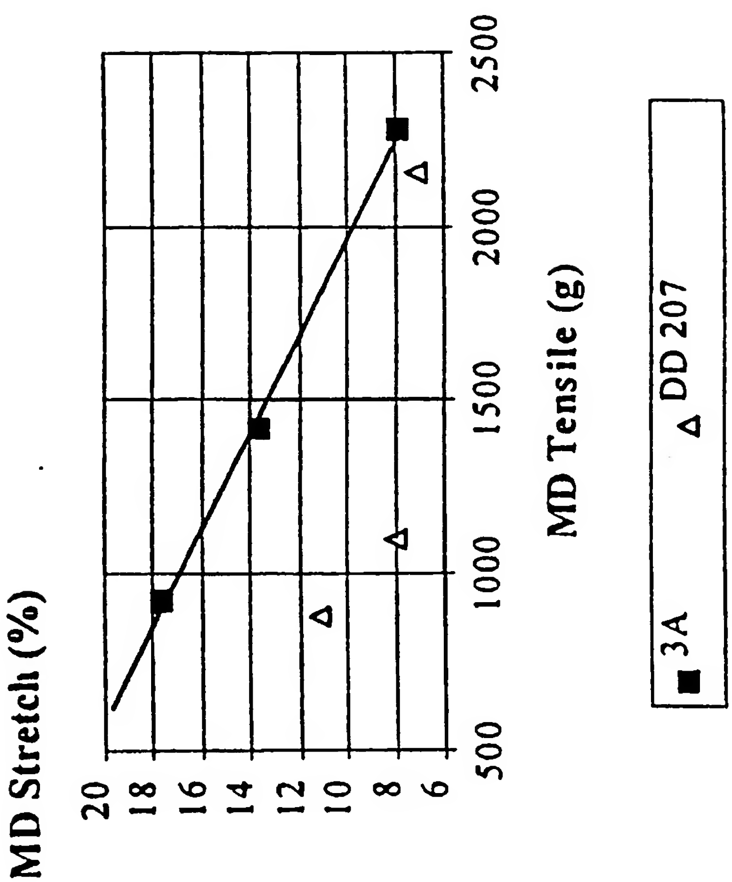

MD Stretch (%)
20
18
16
14
12
10
8
6
500
1000
1500
2000
2500
MD Tensile (g)
3A
DD 207

FIG. 10

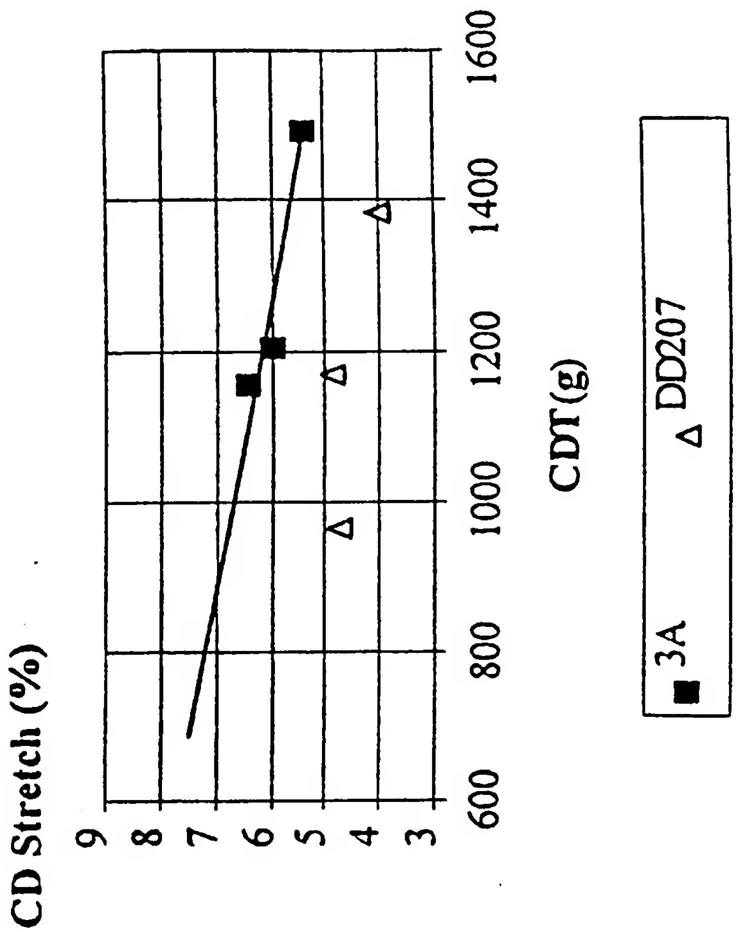


FIG. 11

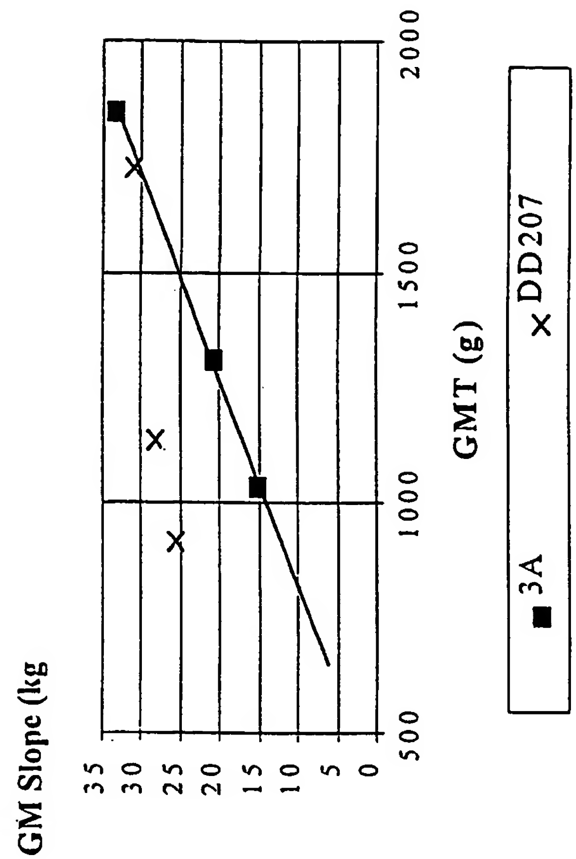


FIG. 12

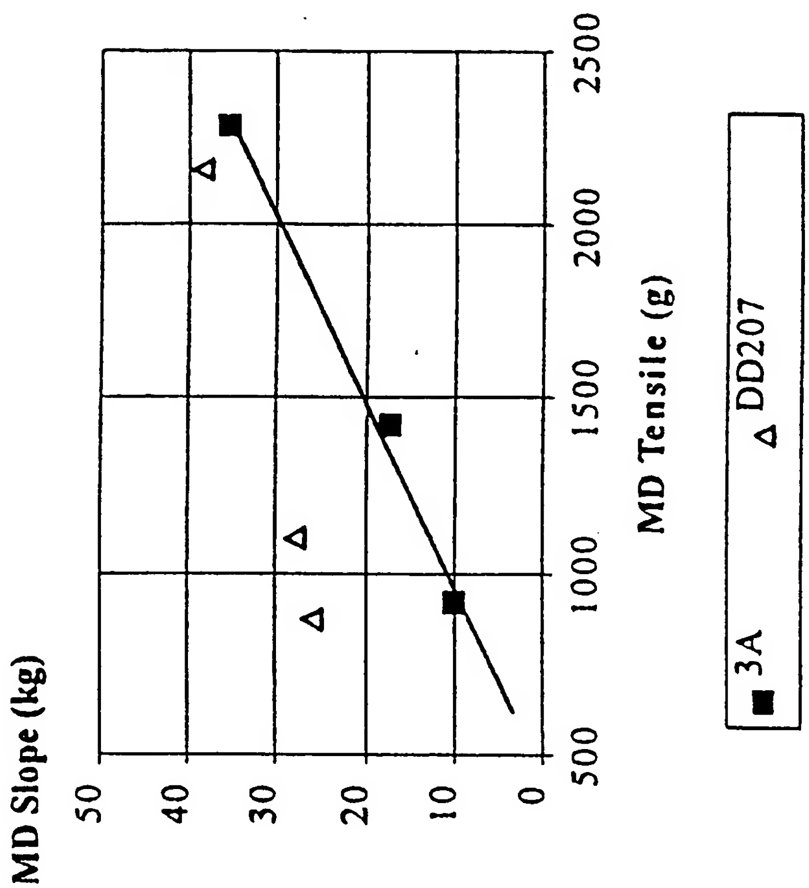

MD Slope (kg)
50
40
30
20
10
0
500
1000
1500
2000
2500
MD Tensile (g)
3A
DD207

FIG. 13

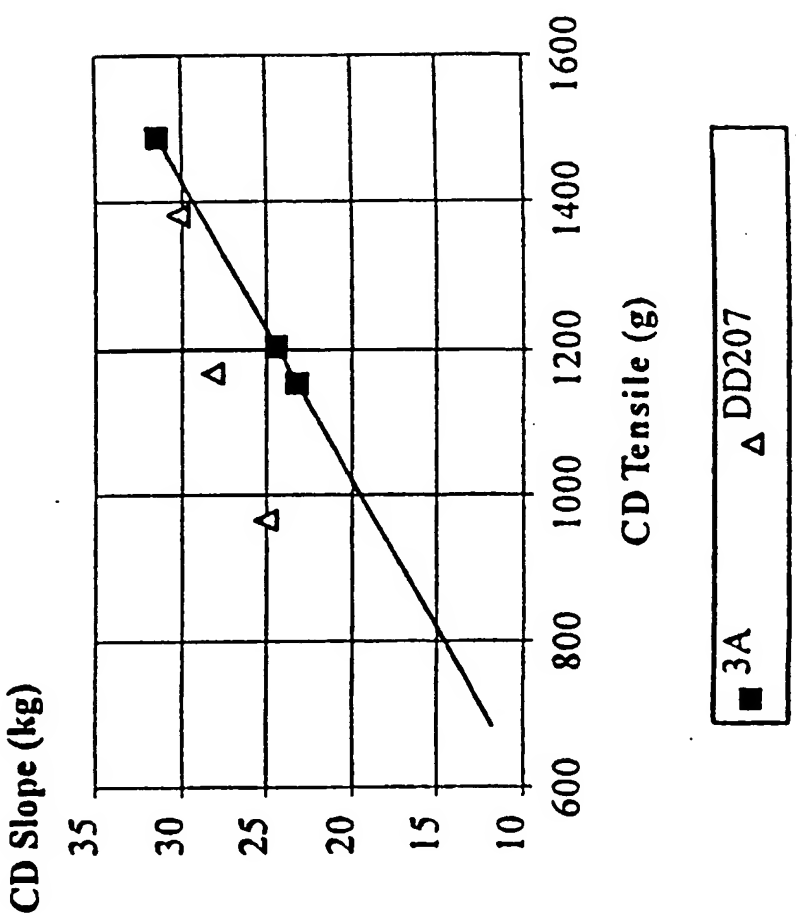

CD Slope (kg)
35
30
25
20
15
10
600
800
1000
1200
1400
1600
CD Tensile (g)
3A
DD207

FIG. 14

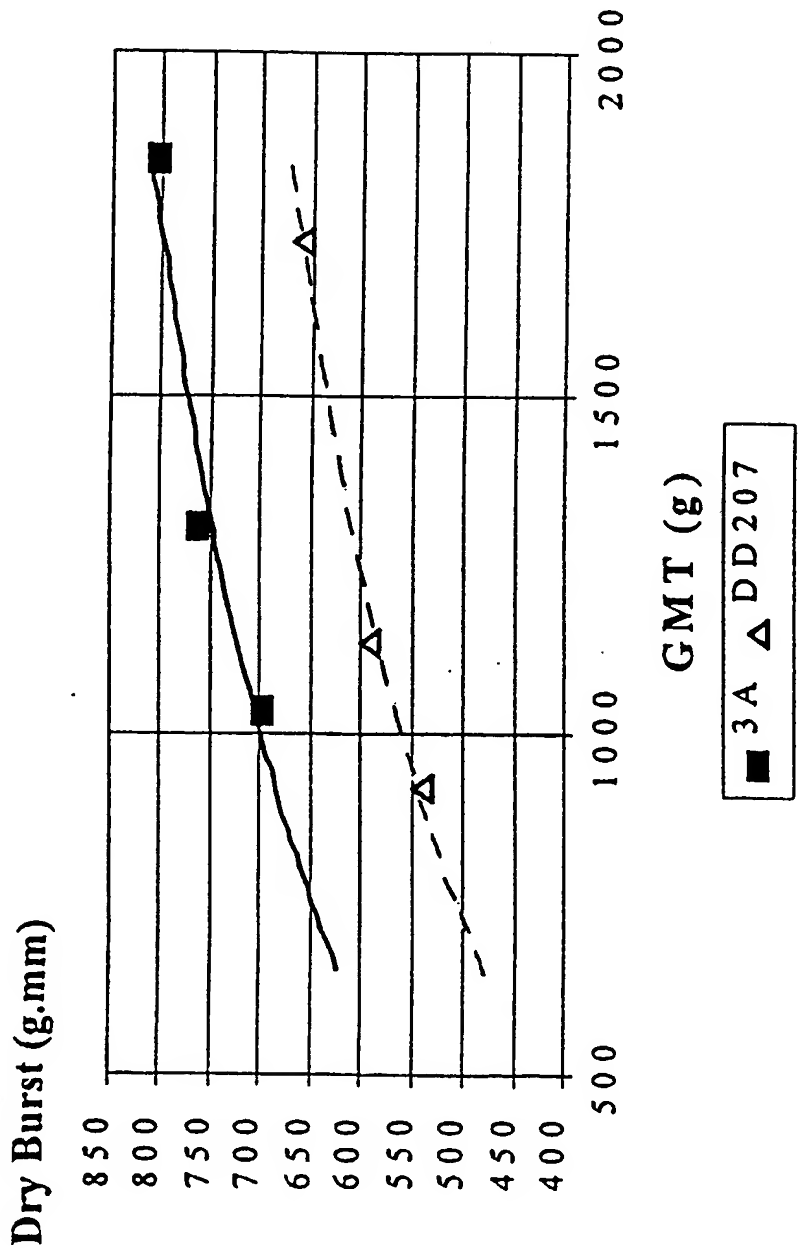

Dry Burst (g.mm)
850
800
750
700
650
600
550
500
450
400
500
1000
1500
2000
GMT (g)
3A
DD207

FIG. 15

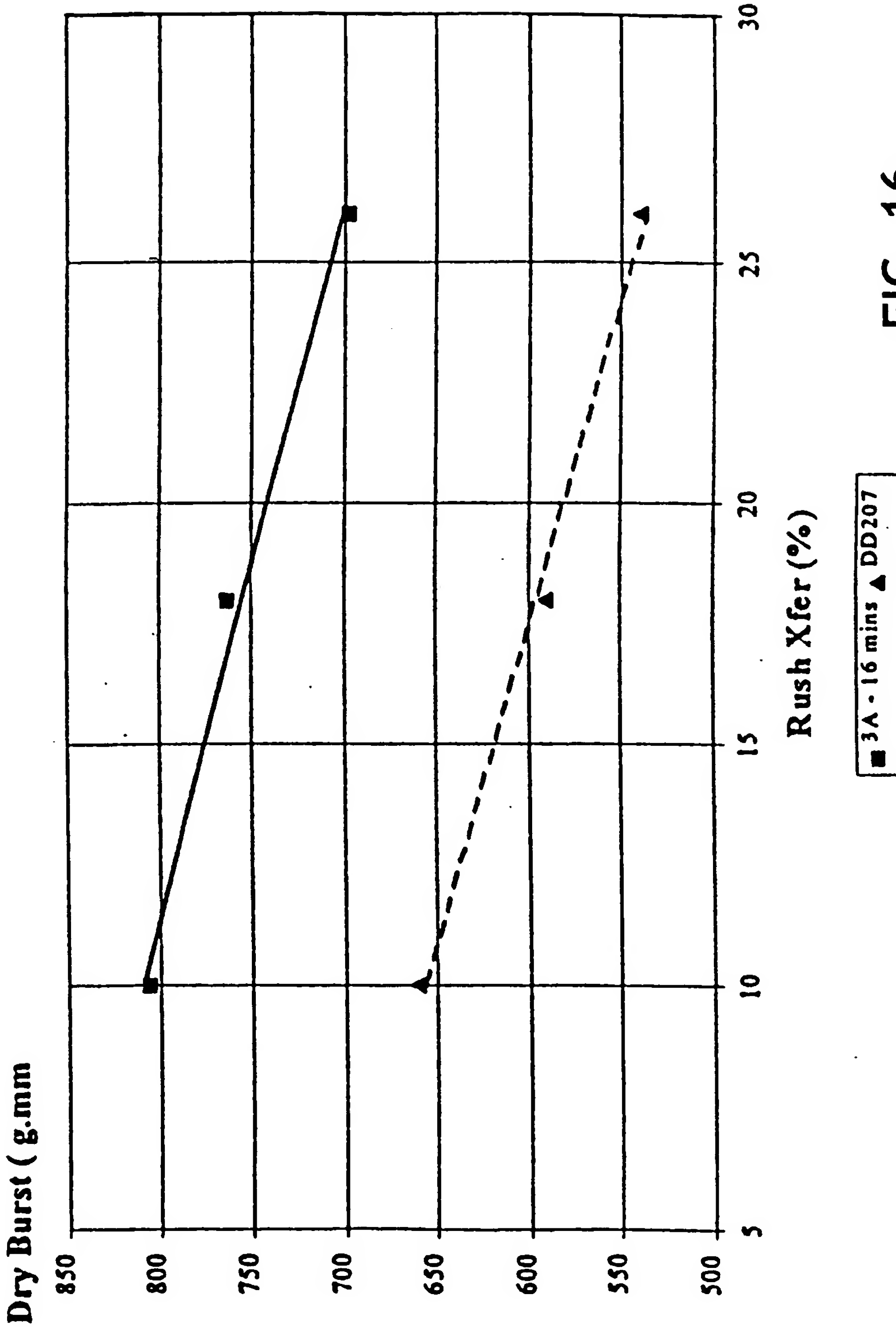

Dry Burst (g.mm
850
800
750
700
650
600
550
500
5
10
15
20
25
30
Rush Xfer (%)
3A - 16 mins
DD207

FIG. 16

Fiber Network Analysis

Z-Direction Structure Analysis

		3A	UCTAD
A. Formation Index (GLH1)			
% COV	=	**8.97**	**7.95**
B. Z-Profile (OF)SU6)			
Ave. % Voids	=	**37.0**	**43.4**
Void Thickness (um)	=	64.7	70.4
Total Tissue Thickness(um)	=	164	161
C. Z-Porosity (TSAI3A)			
Mean Pore Length (um)	=	**36.3**	**45.5**
Std. Dev. in Pore Length (um)	=	49.5	71.3
Vol.-Wt Pore Length (um)	=	183	281
Std. Dev. Vol.-Wet Pore Length (um)	=	157	245
Correct Pore Anisotropy	=	**0.482**	0.424
		(25.7^0)	(23.0^0)

FIG. 17

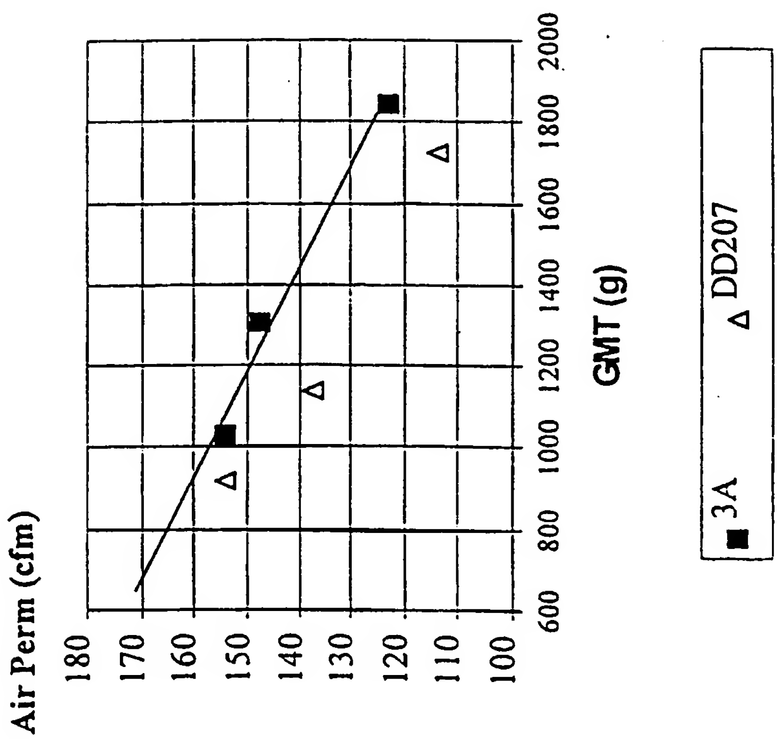

Air Perm (cfm)
180
170
160
150
140
130
120
110
100
600
800
1000
1200
1400
1600
1800
2000
GMT (g)
3A
DD207

FIG. 18

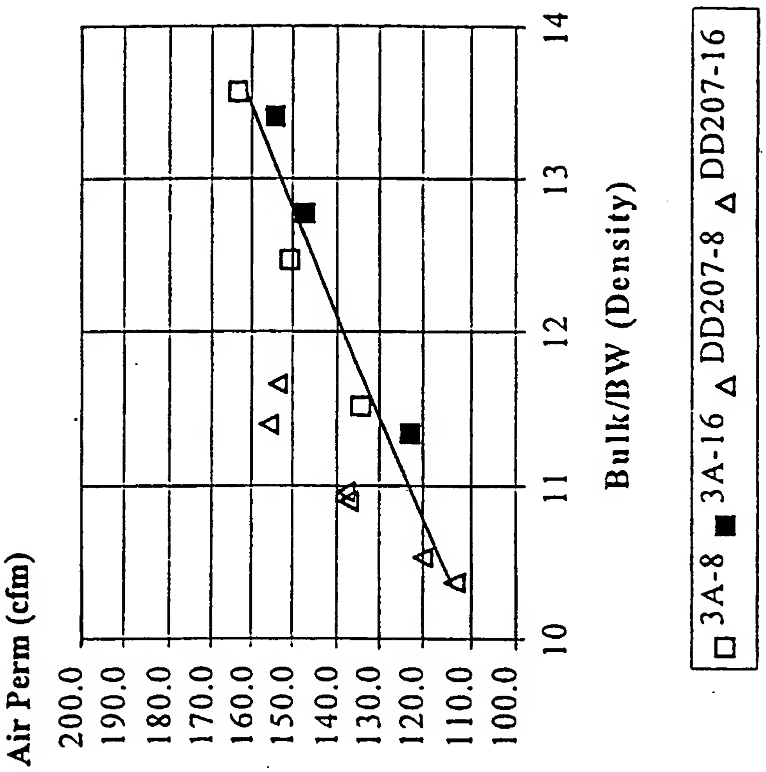

Air Perm (cfm)
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
10
11
12
13
14
Bulk/BW (Density)
3A-8
3A-16
DD207-8
DD207-16

FIG. 19

INTERNATIONAL SEARCH REPORT

Int. onal Application No
PCT/US 99/31320

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D21F11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 677 612 A (KIMBERLY-CLARK CORPORATION) 18 October 1995 (1995-10-18) the whole document	1-3
A	WO 98 01618 A (SCAPA GROUP PLC) 15 January 1998 (1998-01-15) the whole document	1,4,7-9
A	WO 98 19008 A (SCAPA GROUP PLC) 7 May 1998 (1998-05-07) the whole document	1,4,7,9

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 2000	22/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Rijck, F

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/31320

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